- GEOLOGICAL HAZARDS AND RESOURCES (SECTION 5.3 FROM 99-AFC-7)
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GEOLOGICAL HAZARDS AND RESOURCES (SECTION 5.3 FROM 99-AFC-7)

5.3 GEOLOGICAL HAZARDS AND RESOURCES

5.3.1 Affected Environment

The Pastoria Energy Facility site area, including the plant site, associated transmission line, pipelines, and access road, is located at the southern end of the Great Valley physiographic province of California. The Great Valley province and surrounding physiographic provinces are shown on Figure 5.3-1, which also shows the major active and potentially active geologic faults, and instrumentally recorded earthquake epicenters within about 100 kilometers from the site. The geology of the southern portion of the Great Valley province, and the provinces that border it to the south and east, are important to understanding the geologic and seismologic setting of the site area.

The San Joaquin Valley, which makes up the southern two thirds of the Great Valley province, is a northwest-trending structural basin that is filled with approximately 30,000 feet of sediments deposited during Late Cretaceous and Cenozoic time. Sedimentary rocks underlying recent alluvium on the west side of the valley are mostly marine in origin, deposited in an inland sea that persisted in the valley through Pliocene time. Non-marine rocks beneath the west side of the valley are the result of continuing westward tilting and erosion of the Sierra Nevada mountains through geologic time.

The surface of the San Joaquin Valley varies from about sea level near Sacramento, 260 miles north of the site, to about 500 feet above sea level near Bakersfield, 30 miles to the north. The valley is bounded by the Sacramento delta to the north and by mountains of the coast ranges and the Sierra Nevada to the west and east, respectively. At the southernmost end of the valley, in the vicinity of the Pastoria Energy Facility plant site, elevations adjacent to the foothills are on the order of 1,000 to 1,300 feet above sea level. The valley is bounded on the southwest by the San Emigdio Mountains and on the southeast by the Tehachapi Mountains.

5.3.1.1 <u>Regional Geology</u>

Figure 5.3-2 shows the generalized geology of the southeast corner of the San Joaquin Valley in the vicinity of the Pastoria Energy Facility site. The sequence of stratigraphic units that are exposed around the perimeter of the valley and are present at depth below the region are shown on Figure 5.3-3. Significant structural relationships in the site region are illustrated by Cross Section A-A’ on Figure 5.3-4. The location of the cross section is shown on Figure 5.3-2. The locations of more detailed geologic maps, used to characterize subsurface conditions at the plant site and along the routes of the transmission lines and pipelines, are also shown on Figure 5.3-2.

5.3.1.1.1 <u>Physiography</u>. The extreme southern end of the San Joaquin Valley is known as the Tejon Embayment. As shown on Figure 5.3-2, the Tejon Embayment area is surrounded by rock outcrops in the foothills to the west, south, east and northeast. The northwestern boundary of the Tejon Embayment is considered to be the trace of the White Wolf Fault, across which crystalline basement rock (below Late Cretaceous Cenozoic sedimentary-rock sequence) shallows from the main portion of the San Joaquin Valley.

Near the trace of the White Wolf Fault, ground surface within the Tejon Embayment is at an elevation of about 500 feet (see Figure 5.3-2). At the base of the foothills south of the power plant site, the elevation is about 1300 feet above sea level. The ground surface at the base of the foothills consists of an apron of coalesced active alluvial fans of several streams that drain into the Tejon Embayment from the Tehachapi Mountains. Gentle to moderately rugged hills that protrude above the alluvial fans are underlain by eroded sedimentary rocks that are described in Section 5.3.1.1.2.

The plant site area is located on the north-dipping surface of the alluvial fan of Pastoria Creek. The plant site is located about a mile north of the mouth of Pastoria Canyon at the foot of the Tehachapi Mountains. The ground surface dips northward at the plant site at a rate of about 2 feet vertically for every 100 feet laterally. Pastoria Creek runs north-northwestward past the plant site within 1,000 feet to the west.

The proposed transmission line (Route 1) runs westward from the plant site about 700 feet to join the existing transmission line right of way, and then proceeds southward up the alluvial fan about 1.2 miles to the existing Pastoria Substation. The proposed wastewater discharge line (Route 4) runs north-northwestward from the plant site, down the alluvial fan, to the Tejon Oil Field. Slopes up the fan (to the south) are steeper than at the plant site. Slopes down the fan (to the north) are less steep than at the plant site.

The proposed fuel gas pipeline (Route 3) runs along the edge of the foothills to the east and northeast of the plant site, primarily across alluvial fan deposits laid down by streams running northwest and west into the valley. Portions of the route cross exposed or very shallowly buried sedimentary rocks consisting of sandstone, shale, and basalt.

5.3.1.1.2 <u>Stratigraphy</u>. Figure 5.3-2 shows that the mountains nearest to the site, to the south and east, are underlain by granitic and gneissic rocks that were emplaced as part of the Sierra Nevada batholith during Mesozoic time. Cenozoic sedimentary rocks are exposed around the margins of the Tejon Embayment. The uppermost sedimentary formations transition into recent alluvium at increasingly greater depths toward the north end of the Embayment.

Hoots (1930) produced the first map of geologic units surrounding the Tejon Embayment area. His geologic map, which is the only map to cover the entire Pastoria project area at relatively large scale, was used to help evaluate geologic conditions at the plant site and along the associated transmission and pipelines. The legend to Hoots' map is presented on Figure 5.3-5. Hoots' map, at a scale of 1 inch equals a mile, has been enlarged to 1 inch equals 2000 feet, and overlain on maps showing the plant and lines associated with the project. These maps are presented as Figures 5.3-6 through 5.3-9.

More recent mapping of portions of the Tejon Embayment by a number of workers, including Bartow and Dibblee (1981), has been compiled and generalized by Goodman and Malin (1992) at a scale of about 1 inch equals 3,500 feet. That map uses a somewhat different nomenclature that reflects in particular the differentiation of stratigraphic units in oil wells. The following table compares the more recent terminology of Goodman and Malin (1992) with the terminology of Hoots (1930) that is used herein.

Other published mapping of the site area includes a generalization of the Tejon Embayment area following the 1952 Bakersfield earthquake (Dibblee, 1952 - see Figure 5.3-2) and a generalized map of the larger Edison-Maricopa area (Wood and Dale, 1964). Mapping units used for those maps generally lump formations by age and type (i.e., Pliocene, non-marine).

Figure 5.3-3 shows a generalized stratigraphic column for the southern San Joaquin Basin. Units exposed in the foothills south and east of the site, and known to exist at depth beneath the Tejon Embayment, are shown on the right side of the graphic column. Most of those units are non-marine in origin, as opposed the units found on the west side of the basin that are predominantly marine. Sedimentary rocks on the west side of the basin were deposited in a shallow sea. Sedimentary rocks on the east side of the basin, including the Tejon Embayment, were deposited primarily on the flanks of the rising Sierra Nevada Mountains, mostly above the level of the shallow sea.

The uppermost stratigraphic unit is described as recent alluvium. Both Hoots (1930) and Goodman and Malin (1992) distinguish between coarser-grained fanglomerate that is present beneath sloping alluvial fan surfaces near the base of the foothills, and finer-grained alluvium found further toward the center of the basin. In some areas, including the Pastoria site area, the coarser alluvium consists of very coarse sand with gravels up to boulder size. According to operators of the nearby Griffith Company gravel operations, some deposits in the site vicinity contain as much as 70 percent gravels greater than 3 inches across (Drummond, 1999). Larger boulders have been observed to be as large as 8 feet across.

Mapped fanglomerate deposits are highly variable over relatively short distances (tens of feet) due to their mode of deposition. Most of the fanglomerate deposits were deposited by debris flow. These deposits are generally chaotic with high percentages of gravel. Some of the deposits on the alluvial fans were laid down by streams and tend to be more well-graded and sandy. Minor wind-blown and ephemeral lake deposits may also be present.

Fanglomerate deposits dominate the stratigraphic column in the site area, extending back as far as Pliocene time when the Chanac Formation was deposited. Early Holocene-age fanglomerates are elevated above present flood plain levels. Hoots (1930) describes terrace deposits in Tunis Canyon (about 2 miles east of the plant site) to be elevated as much as 100 feet above the present flood plain. Pleistocene age fanglomerate deposits are tilted toward the north, indicating tectonic uplift of the mountains to the south at the end of Pleistocene time. Pliocene fanglomerates of the Chanac Formation are highly deformed adjacent to the San Emigido Mountains, west of the site. In the site area, however, beds of the Chanac Formation are only slightly folded.

The pre-Pliocene sedimentary section includes mainly near-shore marine deposits including sandstones and conglomerates with lesser amounts of shales and marls. Volcanic beds, consisting mainly of extrusive basalts, were deposited in the section during early Miocene time. The oldest beds that are exposed in the site area are also the least coarse-grained. These beds belong to the Eocene-age Tejon Formation and consist of shales with fossiliferous limestone interbeds.

Basement rocks in the site area consists primarily of granitic rocks and associated metamorphic rocks. The granitic rocks are variably described as granodiorite or tonalite. The granitic rocks were emplaced as part of the Sierra Nevada batholith, prior to about 90 million years ago. Most of the granitic rock exhibits some foliation and is therefore considered to be gneissic. Deformed, pre-Jurassic age schists and quartzites are also present as roof pendants.

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5.3.1.1.3 Structure. The regional geologic structure is dominated by a number of large faults that are discussed in more detail in Section 5.3.1.1.4, Seismic Setting. In general, the structure reflects right- lateral strike-slip movement of the Pacific Crustal Plate relative to the North American Crustal Plate, primarily across the northwest-trending San Andreas Fault. The San Andreas Fault is the longest fault in California. It runs from north of San Francisco to the Gulf of California, a distance of over 500 miles.

South of the site, the San Andreas bends to the east as it passes through the Transverse Ranges. In the area of this so called "Big Bend", the north-south compressional component of the plate motion is accommodated not only by right-lateral motion of the San Andreas, but also by left lateral motion on the conjugate Garlock and Big Pine Faults (see Figure 5.3-1) and by reverse faulting on primarily east-trending Transverse Range Faults. Reconstruction of geodetic strain prior to the 1952 Bakersfield Earthquake, which was centered on the White Wolf Fault, show that north-south compression was dominant (Bawden and others, 1997). Following the 1952 earthquake, strain within the Tejon Embayment has been primarily to the northwest, based on recent GPS surveys.

The geologic structure of the Tejon Embayment reflects the present north-south to northwest compressional tectonic regime associated with the San Andreas Fault. It reflects a number of features related to previous tectonic conditions. For example, much of the faulting within the Embayment is related to episodes of basin subsidence and uplift that occurred during most of Cenozoic time (5 to 50 million years ago). Erosional episodes that apparently coincided with periods of uplift are shown on the generalized stratigraphic column for the site area on Figure 5.3-3.

Figure 5.3-4 shows three of the four types of faults interpreted in the site area by Goodman and Malin (1992) on the basis of surficial mapping, seismic reflection profiling, and interpretation of numerous oil well logs. These include the following:

- High angle normal faults that no longer appear to be active.

- Low angle faults that appear to have been associated with the normal faults.

- Left-oblique to reverse faults that lie sub-parallel to the Garlock Fault. The White Wolf Fault, which forms the northern boundary of the Embayment, is a left-oblique reverse fault.

The fourth set of faults identified by Goodman and Malin (1992) consists of thrust faults that ring the U-shaped Tejon Embayment. These include the Pleito Fault that has been mapped along the base of the foothills on the south side of the Embayment, to within a mile south of the Pastoria Energy Facility power plant site. The Wheeler Ridge and Comanche Point thrust faults are blind thrusts underlying large folds on either side of the north end of the embayment.

Crystalline basement rocks, which are exposed in the hill less that two miles south of the plant site, are present within the Embayment at depths on the order of 6,000 to 10,000 feet below ground surface, as shown by structural contours on the top of basement rocks on Figure 5.3-2. The figure shows that Basement rocks north of the White Wolf Fault are between 14,000 and 26,000 feet deep, indicating a structural relief across the fault of 8,000 to 16,000 feet.

Figure 5.3-4 shows that structural relief at the top of basement rocks within the Tejon Embayment is due in part to normal faulting within the basin that occurred on east-trending faults prior to Pliocene time. The remainder of the structural relief is due to more recent thrust faulting around the margins of the basin.

5.3.1.1.4 <u>Seismic Setting</u>. As shown on Figure 5.3-1, several large, active faults are located within the site region. Strong seismic shaking has been experienced in the site vicinity due to previous earthquakes associated with several of those faults. It is virtually certain that the site will experience strong seismic shaking due to future earthquakes.

Thirteen of the largest historic earthquakes that have been felt within about 100 miles of the site are listed in Table 5.3-2. The table lists the date that the earthquake occurred, its location, the reported depth and magnitude for the event, and the reported intensity of shaking experienced near the source. It is apparent from the table that some of the strongest shaking recorded occurred during the July, 1952 earthquake centered between the site and Bakersfield on the White Wolf Fault.

The Bakersfield Earthquake caused heavy damage to structures in populated areas, broke pipelines, bent railroad rails beyond further use, and caused ground rupture in several areas. The ground rupture was due primarily to reverse left lateral movement on the White Wolf Fault zone, which in some areas was observed to be several hundred feet wide (Dibblee, 1955). Other ground failures were associated with landslides caused by the shaking, liquefaction in areas of shallow groundwater and loose soils (including across lower Comanche Creek on Route 3 for the present project), and differential settlement in areas of variable density soils.

Significant shaking has occurred in the site area as a result of other earthquakes such as the 1857 Magnitude 8+ Fort Tejon Earthquake and the 1994 Magnitude 6.8 Northridge Earthquake. The population of the area was nearly zero in 1857, so that if any ground failure did occur, it remained unreported. During the 1994 earthquake, shaking intensity of VII (very strong) was reported south of Bakersfield. No damage was reported.

5.3.1.1.5 **Significant Quaternary Faulting**. Future strong seismic shaking can come from any one of a number of potential seismic sources in the site region. Most previous earthquakes have occurred on faults that had been, or could have been recognized at ground surface. The Tejon Pass (1857) earthquake, and the 1952 Bakersfield earthquakes are examples of earthquakes with readily causatibe faults (San Andreas and White Wolf Faults, respectively). Some recent earthquakes, however, have occurred on blind thrust faults that were evidenced by folding and/or minor faulting at ground surface. Notable blind thrust earthquakes include the 1994 Northridge Earthquake and 1987 Whittier Narrows Earthquake.

Table 5.3-3 is a listing of known active (Holocene activity) and potentially active (Quaternary activity) faults within 100 kilometers of the site that could generate significant shaking at the site. Most of those faults have a recognized surface trace and are shown on Figure 5.3-1. The blind thrust listed in the table is the Northridge blind thrust that was the source of the 1994 earthquake. That fault is suspected of being associated with the Oakridge Fault that does have a surface trace.

Similar associations may occur near the site. The Wheeler Ridge blind thrust appears to be associated with both the Pleito Thrust and the White Wolf Fault. Based on map patterns, the Comanche Point Blind Thrust appears as if it may also be associated with the White Wolf Fault.

Table 5.3-3 also indicates the style of displacement expected on the fault, its classification according to the California Building Code (CBC, 1998), measured and published distances to the fault from the proposed Pastoria Energy Facility project site, estimated slip rate, and estimated maximum magnitude for a future earthquake. The CBC source type is given as A for historically active faults, B for faults that show evidence of movement during Holocene time (the last 11,000 years), and C for faults for which evidence of Quarternary (past 2 million years) movement has been documented.

The table shows that the closest faults to the proposed power plant site are the Pleito Thrust and the Garlock Fault. The map book designed to be used with the CBC 1998 (CDMG, 1998) shows the Pleito, a Type B fault, to have been mapped to about 2 kilometers west of the site. More recent mapping compiled by Goodman and Malin (1992), however, shows the fault to be only about 1 kilometer south of the site. The Garlock Fault is a Type A fault and is located about 9.5 kilometers south of the site. The White Wolf Fault is 16 kilometers north of the power plant site. The San Andreas Fault runs about 16 kilometers to the southwest.

Other faults are known to be present within the Tejon Embayment, between the Pleito and White Wolf Faults. These include the Springs Fault, shown on Figures 5.3-4 and 5.3-7. There is some evidence that the Springs Fault has experienced displacement during historic times, possibly during the 1952 Bakersfield Earthquake. However, the mapped Springs Fault is very short (less than15 km) as are the faults identified in the subsurface by Goodman and Malin (1992). It is therefore unlikely that these faults could produce seismic shaking of a greater intensity than is possible from the Pleito and Garlock Faults.

The following paragraphs provide a summary of information known about each of the faults shown on Table 5.3-3, which are considered to be significant potential seismic sources for the site.

Pleito Fault. This south-dipping thrust fault is part of the complex zone of thrust faults and folds that were originally mapped west of the project site at the base of the San Emigdo mountains, extending east of the Grapevine (Interstate Route 5 at the base of the mountains) to within 4 miles of the Pastoria Energy Facility project site (Troxel and Morton, 1962). More recent mapping compiled by Goodman and Malin (1992) shows the Pleito Fault running along the base of the foothills within a mile south and southeast of the site. It appears as if the fault, or one of the faults that appears to be associated with the Pleito Fault, forms the mountain front structure for the Tehachapi Mountains.

Based on an interpretation of the fault near the Pastoria site (Goodman and Malin, 1992), the fault dips shallowly to the south beneath the hills at between 20 to 40 degrees from horizontal. The site is not on the upper place of the Pleito Fault, but may be on the upper plate of a fault that runs parallel to the Pleito beneath the alluvium-filled Tejon Embayment.

At its western end, the Pleito Fault has been shown to have moved between 345 and 1465 years ago. A slip rate of 1.4 mm/year has been assigned to the fault. Wesnousky (1986) assigned a characteristic magnitude of 7.0 to the fault, and a return period of 1470 years.

White Wolf Fault. The trace of the White Wolf Fault is known from rupture during the 1952 Bakersfield Earthquake. The main trace runs from near Wheeler Ridge in a northeast direction to Comanche Point and beyond. Northeast of Comanche Point, it runs along the mountain front. The total length of the fault is about 60 km. (Dibblee, 1955). During the 1952 Earthquake, left-lateral and reverse offset was observed on the steeply south-dipping fault. Maximum offset observed was 4 feet vertically (up to the southeast) and 4 feet laterally (Buwalda and St.Amand, 1955).

Subsurface exploration has shown that the depth to granitic basement rocks on the southeast side of the fault is about 10,000 feet more shallow than on the northeastern side. According to Stein and Thatcher (1981), the White Wolf Fault separates the area of active uplift in the Tehachapi Mountains from the area of continuing subsidence in the San Joaquin Valley. They estimate the return period for large earthquakes on the fault to be between 170 and 450 years.

Garlock Fault. The Garlock Fault is considered to be one of the most prominent faults in southern California. Its trace is readily apparent from its intersection with the San Andreas Fault near the town of Frazier Park, to its eastern end in the Mojave Desert, about 250 km to the east. The slip rate on the left-lateral strike-slip fault is estimated to be between 2 and 11 mm/year. It is thought that the western end of the fault may move on the average of once every 200 years.

Ground cracks were observed along the Garlock Fault following the 1952 Bakersfield earthquake. Other cracks formed following groundwater removal from the Freemont Valley, east of the Tehachapi Mountains. A magnitude 5.7 earthquake occurred on the Garlock trend near the town of Mojave in 1992, possible triggered by the Landers Earthquake. No surface movement was observed as a result of that earthquake.

San Andreas Fault. The San Andreas Fault is the main, active, crustal discontinuity that separates the northwest moving Pacific plate from the southeast moving North American plate. This right lateral strike slip fault extends from the Gulf of California northward along the western edge of California, then extends offshore north of San Francisco. Historically, the San Andreas Fault has produced earthquakes up to about magnitude 8.

As discussed by the USGS (1988), the fault can be divided into several discrete segments along its length, based on differing seismic characteristics. Northwest from the Coachella Valley, the following segments (and approximate segment lengths) of the San Andreas Fault have been identified: the Coachella segment (200 km); the San Bernardino Mountains segment (100 km); the Mojave segment (100 km); the Carrizo segment (145 km); and the Cholame segment (55 km). In future earthquakes, these segments may rupture separately or together, as occurred in the 1857 Ft. Tejon earthquake (M7.9) when the Cholame, Carrizo, and Mojave segments ruptured. That portion of the fault has also been referred to as the south-central segment, and is the closest portion of the fault to the site.

Work by Sieh and others (1989) and Grant and Sieh (1994) provides evidence of large earthquakes occurring, on the average, about every 140 to 160 years on the south-central segment of the fault. Based on the USGS (1988), a slip rate of 34 mm/year is assumed for this portion of the fault.

Big Pine Fault. This steeply north-dipping, left-lateral reverse fault located near Frazier Park shows evidence of Late Quaternary displacement near its intersection with the Pine Mountain Fault (Jennings, 1994). Rupture may have occurred on the fault in 1852, although the displacement is thought to have been due to landsliding instead of tectonic movement (Townley, 1939).

San Gabriel Fault. The San Gabriel Fault may have been an ancient segment of the San Andreas Fault that had large lateral displacements during later Tertiary time. Since early Pleistocene time, the San Gabriel Fault appears to have been bypassed by the current traces of the San Andreas Fault, and activity on the San Gabriel Fault has subsequently diminished. However, Bull *et al.* (1979) show evidence of Quaternary displacement on the San Gabriel Fault. Additional evidence of some Quaternary and possible Holocene displacements has been reported along the San Gabriel Fault trace in the Saugus/Castaic area (Cotton, 1986).

Ozena Fault. The Ozena Fault is a north-dipping reverse fault, about 40 km in length, at the southern end of zone of NNW-trending faulting that includes the South Cuyama Fault. Evidence has been found for Quaternary displacement (Jennings, 1994)

Pine Mountain Fault. The Pine Mountain Fault is a steeply north-dipping reverse fault that is about 59 kilometers long. It is associated with the Big Pine Fault. It appears to have been displaced in Late Quaternary time (Jennings, 1994).

Santa Ynez Fault. The Santa Ynez Fault Zone is recognized as a strong linear feature from the San Gabriel Fault to Point Arguello, a distance of slightly more than 61 miles (97 km). Portions of the fault are about 25 miles (41 km) from the site. The near surface dip appears vertical. Eocene sediments are faulted south side up nearly 9500 feet. Left slip displacement has been estimated from 9 to 37 miles. According to Dibblee (1966), the fault has displaced stream courses from a few hundred meters to as much as 5 km (3 miles), and older alluvium may be displaced by the fault in the vicinity of Matilija Creek. The age of last displacement is estimated to be late Quaternary (CDMG, 1975).

San Cayetano Fault. The San Cayetano Fault is composed of a zone of gently to moderately north dipping thrust faults that extends eastward about 12 miles (19 km) from the eastern edge of the Ojai Valley to Sespe Creek. In Sespe Creek, approximately 30,000 feet of displacement in Cretaceous rocks is recognized (Fine, 1954). The fault has produced scarps and linear fault features that displace Quaternary gravels at least 200 to 300 feet on the north side of the fault. Based on youthful geomorphology, the fault is considered to be Holocene and therefore active (CDMG, 1975).

Arroyo Parida Fault. The Arroyo Parida is the longest of three faults mapped along the southern flank of the Santa Ynez Mountains (Jennings, 1994). It has a history of Quaternary displacements including probable Holocene offset. The most recent dated surface rupture is about 30,000 years old. Its slip rate is estimated at less than 0.5 mm/year (Peterson and Wesnousky, 1994).

Oakridge/Northridge Blind Thrust. The Oakridge Fault system is considered to be comprised of the onshore portion of the Oakridge Fault, and the Northridge blind thrust, a previously unrecognized fault beneath the San Fernando Valley and the Santa Susana Mountains that produced the January 17, 1994 Northridge earthquake. The onshore Oakridge Fault extends approximately east-west a total of 53 kilometers. The Northridge blind thrust is estimated to extend farther east of the Oakridge Fault, for approximately 27 kilometers. From seismological and geodetic evidence, the Northridge Blind Thrust dips approximately 30 to 40 degrees to the south, and trends roughly east-west. The zone of aftershocks defines a fault plane that is approximately 25 to 30 km in length, extending to a depth of approximately 20 km. The San Fernando Valley is located above the inclined fault plane.

During the Northridge earthquake, the San Fernando area moved up and to the north in a thrusting motion (Donnellan, 1994). The source fault is described as "blind" because it does not appear to reach the ground surface. It has been hypothesized that the "Northridge Blind Thrust" is a subsurface extension of the Oakridge Fault (Yeats, 1994a,b; Yeats *et al*., 1994; Donnellan, 1994).

A minimum slip rate of 1 mm/year for the Northridge Blind Thrust is estimated by Davis and Namson (1994). An upper bound slip rate of 5 mm/year is estimated from direct correlation with the slip rate of the Oakridge Fault (Yeats, 1983; 1988; 1994a; 1994b). The best estimate slip rate of 2.5 mm/year is derived from the slip rate budget considering the GPS convergence rate of 4-5 mm/year, and the sum of the best estimates of slip rate for the Santa Susana Fault and Mission Hills segment of the Sierra Madre Fault zone.

Santa Susana Fault. The Santa Susana Fault is a range front fault that extends along the western portion of the Santa Susana Mountains for a distance of about 20 miles (32 km). According to Ziony *et al.* (1974), the eastern portion of the fault has experienced Pliocene displacement; if the Olive View Faults are considered part of the Santa Susana Fault, then

Pleistocene displacement can be attributed to the fault. Surface displacements were mapped along its trace following the 1971 magnitude 6.4 San Fernando earthquake. However, there is some question as to whether these surface features represented surface fault rupture, partly because no movement was recorded on the fault plane where it is penetrated by numerous wells in the Aliso Canyon gas storage facility. A slip rate of 3 mm/year is assigned to this fault, based on the fault's assumed association with the Sierra Madre Fault system. Ziony and Yerkes (1985) associate scattered small earthquakes with the Santa Susana Fault, including a magnitude 4.6 event in 1976.

Sierra Madre Fault System. The Sierra Madre Fault system forms a prominent east-west structural zone along the south side of the San Gabriel Mountains and consists of a complex system of northward-dipping (12 to 70 degrees) left lateral-reverse faults along which the mountains have been uplifted. Crook *et al.* (1978 and 1987) indicate that this 50+ mile-long fault system tends to rupture in discrete structural segments during earthquakes.

Based on the work of Crook *et al.* (1978 and 1987) and Clark *et al.* (1984) regarding recent activity and slip rates along the fault system, the Sierra Madre Fault system has been subdivided into several segments that appear to rupture independently. From west to east, the segments (and their approximate lengths) considered in this analysis include: the Mission Hills segment (7 km); the San Fernando segment (19 km); the Dunsmore segment (17 km); and the Sierra Madre segment (14 km). Based on work by Clarke *et al.* (1984), a slip rate of 3 mm/year is assumed for all four segments.

The San Fernando Fault ruptured in 1971, causing the moment magnitude (M_w) 6.6 San Fernando earthquake. The zone of surface rupture associated with this earthquake extended discontinuously for approximately 9 miles with a maximum measured vertical displacement across the entire fault zone of 7.9 feet, with the north side up. Although no surface rupture occurred, the 1991 Sierra Madre earthquake (M_w 5.6) has been attributed to the Sierra Madre segment.

5.3.1.1.6 Potential Geologic Hazards. Geologic hazards that are known to be present in portions of California, and that could possibly affect the power plant site or the routes planned for transmission and pipelines, are described and discussed in the following paragraphs. The potential for the following hazards are evaluated in general terms in this section and discussed further in relation to the plant site and the linear roots in the following sections:

- Ground shaking
- Ground rupture
- Liquefaction
- Slope failure
- Seismically-induced settlement

- Subsidence
- Collapsible soils
- Expansive soils
- Flooring
- Erosion and sedimentation.

Table 5.3-4 lists these potential hazards and indicates which project elements may be affected by them.

Ground Shaking. By far the most severe geologic hazard with the potential to affect the site area is strong seismic shaking that can be expected from future earthquakes in the site region. The strong shaking will directly affect the design of structures planned for the Pastoria Energy Facility. It could also result in secondary hazards such as liquefaction or seismic settlement that are addressed in later paragraphs.

In order to estimate the level of shaking that can be expected at the site, a deterministic evaluation was made according to the 1998 California Building Code (CBC). The code requires that the following steps be completed to select appropriate seismic coefficients for use in structural design:

- Determine the seismic zone in which the project is located (CBC Figure 16A-1).

- Select a site soil profile based on testing of site soils (CBC Table 16A-J).

- Select a preliminary value for seismic coefficient Ca based on the seismic zone and the soil profile (CBC Table 16A-Q).

- Select a preliminary value for seismic coefficient Cv based on the seismic zone and the soil profile (CBC Table 16A-R).

The initial determination was that the site is within Seismic Zone 4, which requires the following additional steps:

- Using a map book especially prepared by the state to be used with the CBC (CDWR, 1998), determine fault types and distances for faults near the site.

- Based on fault types and distances, select near-field values Na and Nv to be used to modify coefficients Ca and Cv respectively.

In order to determine the characteristic soil profile for the site as required by the CBC, a downhole seismic velocity survey was conducted at a 100-foot deep boring that had been completed during the geotechnical investigation of the power plant site. The following velocity values were obtained from the survey:

	Seismic Velocity, fps	
Depth Range, feet	Compressional Wave	Shear Wave
0 – 16	1,350	600
16 – 60	2,350	1,540
60 – 100	3,950	2,170

An average shear wave velocity value of 1357 fps was determined for the site using equation 36A-1 from the CBC. Based on that average shear wave velocity, the site is classified as Sc (very dense soil site) according to CBC Table 16-A-J.

Using Seismic Zone 4 and a site soil type Sc, the following preliminary seismic coefficients were selected: Ca = 0.40Na; Cv = 0.56 Nv. Na and Nv values were determined to be 1.3 and 1.6, respectively, based on the proximity of the Pleito Fault to the site, resulting in the following final values:

Ca = 0.40 * 1.3 = 0.520   Cv = 0.56 * 1.6 = 0.896

The coefficients provide shaking levels, in fractions of the value of gravity, for use in specified foundation and structural design elements.

Ground Rupture. This potential hazard is defined as ground breakage along the trace of a fault during an earthquake. Other forms of ground failure, such as liquefaction and seismically induced settlement, are discussed in later paragraphs.

Both the White Wolf Fault to the north of the power plant site, and the Pleito Fault, which has been mapped less than a mile south of the site, have been zoned as Earthquake Hazard Zones by the State of California (Hart *et al*., 1984). Assignment of Earthquake Hazard Zones is an acknowledgement by the State that the probability of future surface rupture within 0.25 mile of known Quaternary surface fault traces is significant.

Sites that lie within an Earthquake Hazard Zone require investigation for possible surface rupture prior to construction of buildings for human habitation. For the Pastoria project, this requirement would formally apply only to structures at the power plant site where people may work. However, the possibility of surface faulting should be considered for the plant site and associated linear elements from the standpoint of cost effective design. It may be possible to design these elements to tolerate possible surface rupture, or to be easily repaired following rupture, should it occur.

The Springs Fault, which is shown by Jennings (1994) to be a Quaternary Fault that runs about a mile and a half north of the power plant site, has not been zoned by the state. Route R3 (fuel gas pipeline) crosses the Springs Fault at approximately Milepost 6.75 (see Figure 5.3-7). Route R4 (waste water discharge line) crosses the projection of the Springs Fault, at approximately Milepost 1.5 (Figure 5.3-6), within the limits of the Tejon Oil field. It should be noted that Goodman and Malin (1992) show several other faults, associated with the Springs Fault, to be present in the vicinity of the oil field.

The White Wolf Fault is well north of the power plant site, but does include the northernmost portion of Route 3 (primary alternative) for the fuel gas pipeline. The route approaches the mapped trace of the White Wolf Fault at about Milepost 15, where it turns northeast to parallel the fault for about a mile. Although the northern terminus of the route is south of the White Wolf Fault, other mapped faults in the area, which may be associated with the Comanche Point Blind Thrust, should be considered as possible surface rupture hazards (see Figure 5.3-9).

The zoned portion of the Pleito Fault is more than three miles west of the power plant site. However, Goodman and Malin (1992) have mapped the fault within a mile south of the site (see Figure 5.3-6), and have interpreted parallel faults beneath the alluvium in the more immediate vicinity of the power plant, as shown on Figure 5.3-4. Therefore, the possibility of future fault rupture at the power plant site, and along linear routes near the site, should be considered.

With respect to possible surface faulting, it should be noted that no evidence has been found that the faults shown by Goodman and Malin (1992) in the site vicinity (see Figure 5.3-4) offset alluvial fan deposits near ground surface. As part of the geotechnical investigation for the site, an analysis of aerial photographs of the site and vicinity was conducted for indications of possible surface faulting. Only one possible lineament was observed. That lineament is a weak tonal contrast trending east-northeast about a 0.5 mile south of the plant site. The lineament was field checked and found not to be associated with topographic or surface texture changes that might indicate a fault. The lineament crosses linear Route 1 (transmission line) at approximately Milepost 0.5.

Liquefaction. This potential hazard is associated with strong seismic shaking in areas of relatively loose granular soils and shallow groundwater. Under those conditions, the application of seismically-induced shear stresses can cause pore water pressure to rise, which results in a loss of soil strength that adversely affects the stability of foundations of buildings and other structures that rely on the soil strength. In extreme cases, the ground overlying the liquefied horizon cracks and pore water is ejected from cracks. Cracked ground and “mud volcanoes” that resulted from liquefaction during the 1952 Bakersfield Earthquake were observed in the vicinity of lower Comanche Creek (Dibblee, 1955), near the northernmost terminus of Route 3B.

Borings recently conducted at the power plant site indicated that soils are generally very coarse-grained (predominantly gravelly coarse-grained sands) and are dense to very dense below the upper 1 to 2 feet of surficial soils. Even if these sediments were saturated, it is likely that they are too permeable to liquefy. Borings at the plant site did not encounter groundwater within the upper 100 feet below the site. The actual depths of groundwater at the plant site and along the linear alignments are not known, but can be estimated from regional data.

Regional water table in the central portion of the Tejon Embayment in 1992 was on the order of 500 feet below ground surface (Kern County Water Agency, 1993). A well monitored by the California Department of Water Resources (CDWR, 1999) located about 5 miles west of the power plant site (State Well Number 10N19W08A01S) indicates that water table is more than 1,000 feet below ground surface. Regional groundwater, therefore, does not appear to be shallow enough to be potentially involved with liquefaction.

Perched groundwater could be present at a number of locations within the project area. It is likely that groundwater is shallow, possibly perched, at the mouth of Comanche Creek where liquefaction occurred in 1952. For this reason, liquefaction at the northern terminus of Route 3B (fuel gas pipeline alternate, mileposts [MP] 16 through 18.5) should be considered a possibility. Locations where Routes 3, 3A, and 3B cross the mouths of other stream valleys should also be evaluated for shallow groundwater and fine-grained granular sediments that could result in liquefaction during the next strong earthquake. Other valley crossings that should be considered include Tejon Creek (MP 12 to 15), El Paso Creek (MP 5 to 7), and Tunis Creek, (MP 3.5 to 4.5).

In the vicinity of the power plant site, perched water could be associated with Pastoria Creek, which flows from Pastoria Canyon about 1 mile south of the site and flows northward about 1,000 feet west of the site. Reconnaissance of the stream in the summer of 1999 indicated a stream flow of about 20 to 30 gallons per minute at the Edmonston Pumping Plant Road, and only about half of that rate nearest the power plant site. It appears, therefore, that 10 to 15 gallons per minute percolate into the ground within a mile upstream of the site.

It is not likely that percolating water from Pastoria Creek is perched in the site vicinity. Borings completed at the site encountered no groundwater and no fine-grained layers that may restrict vertical flow of water. A percolation test completed at the site of the plant septic tank leach field measured vertical percolation rate of about 11 feet per day in coarse sands with cobbles at two feet below ground surface. The soils observed in the borings appear to be very similar to those observed in the percolation test pit. It is considered likely, therefore, that the measured percolation rate may apply at depth beneath the site.

As discussed above, perched water may be present at the mouths of streams running out of the mountains to the east and northeast of the power plant site. Shallow water is also present on the south side of the Springs Fault, as evidenced by springs along its projected trace (see Figure 5.3-7).

Slope Failure. Neither the power plant nor any of the linear elements (transmission and pipelines) are planned to cross particularly steep topography. The potential for the failure of natural slopes that might affect the project is, therefore, considered to be very low, with the possible exceptions discussed below.

Portions of the fuel gas pipeline alternate alignments (Routes 3, 3A, and 3B) cross areas of adverse bedrock dip (out of slope). The most apparent case of out-of-slope dip occurs as Route 3B curves around Comanche Point. Project plans indicate that the route is below low bluffs of sandstone (Vaqueros Formation as defined by Hoots, 1930). Northerly dips of between 26 and 49 in that area appear to be steeper than the slope of the low bluffs, indicating that slope failure is not likely.

The gravel excavation, located about 1,000 feet east and southeast of the power plant site, is the only significant topographic relief in the immediate site area. That pit is presently 100 feet deep and is not expected to be taken deeper or closer to the site (Drummond, 1999). Considering the flat ground between the plant site and the excavation, and the absence of a liquefaction potential, it is considered unlikely that a slope failure at the gravel operation could affect the site.

The transmission line route (Route 1) extends into the foothills south of the site. A small slope failure was noted during excavation of the California Aqueduct canal near the transmission line crossing. That slide occurred as the canal was being excavated across a rock nose immediately west of Pastoria Creek. At the location of the slope failure, bedding was found to be dipping adversely out of slope. The new transmission line will run on alluvium and will not rely on the rock that failed nearby for stability.

Seismically-Induced Settlement. Seismically induced settlement occurs when relatively loose soils consolidate under the weight of a surcharge or structure during earthquake shaking. Borings completed at the plant site indicate that the soil is relatively dense from near ground surface. It does not appear likely, therefore, that site structures will experience unusual settlement due to seismic shaking.

Subsidence. Regional subsidence due to fluid withdrawal (petroleum and groundwater) has been documented in the southern San Joaquin valley, north of White Wolf Fault. In an area 12 miles north of the site, on the southern side of a subsidence bowl centered further to the north, subsidence through 1964 was on the order of 1 foot (Wood and Dale, 1964). No subsidence was reported closer to the site. This appears to be in part because of the coarser-grained sedimentary rocks and alluvial units in the Embayment as compared to finer grained sedimentary rocks in the deeper parts of the San Joaquin basin further north and west from the site area.

Even though both groundwater and petroleum have been removed from the ground within the Tejon Embayment, there is no evidence that significant subsidence has occurred, or may occur in the future, in the project vicinity. The likelihood of seismically induced settlement is, therefore, considered to be remote.

Collapsible Soils. Soils that collapse due to the addition of water are known to be present at the southern end of the San Joaquin Valley. Soils with a potential for collapse were identified along the route of the California Aqueduct (CDWR, 1972) as debris flow deposits on alluvial fans. These deposits were described as poorly sorted mixtures of clay, silt, sand, and gravels, cobbles and boulders that were deposited very wet and that dried before consolidating, leaving small air bubbles and other open structure in the resulting soil. Re-wetting of these soils causes chemical and physical bonds between soil particles to weaken. This allows the open structure of the soil to collapse and the ground surface to subside.

Long reaches of the California Aqueduct alignment were pre-flooded prior to construction of the canal due to the possibility of collapsible soils. In two areas near Wheeler Ridge, between 10 and 12 miles west of the Pastoria plant site, some ponds constructed for pre-flooding subsided between 0.5 and 1.75 feet when water was added. Other ponds in those areas subsided very little (less than 0.2 feet) illustrating the variability of collapse that can occur in a collapse-prone area (CDWR, 1972).

According to the CDWR (1972), no other area of pre-flooding along the canal route between Wheeler Ridge and the Edmonston Pumping Plant, apparently including the area near the Pastoria Plant site, experienced as much as 0.2 feet of collapse. However, in the Pastoria plant site area, the aqueduct runs along the edge of the foothills where bedrock is at ground surface or shallowly overlain by alluvium and colluvium. The plant site is further down the alluvial fan where thicker debris flow deposits are likely to have accumulated.

A visual examination of soils from borings and test pits was completed as part of the geotechnical investigation of the plant site. Observed soils were virtually all coarse-grained and predominantly non-cohesive. In order to collapse, soils must have at least a weak cementation or cohesion that can be modified by the addition of water. It does not appear, therefore, that the soils are collapsible. Laboratory testing of soil samples for collapsibility is being conducted as part of the geotechnical investigation of the site. Additional laboratory testing will be conducted in areas where transmission line and pipeline routes associated with the project cross alluvial fans that could potentially contain collapsible soils.

Expansive Soils. Soils that contain significant amounts of clays, such as bentonite that expand when wetted, are considered to be expansive. Expansive soils beneath foundations can cause foundation damage if moisture collects beneath the structure from irrigation or capillary rise from shallow groundwater.

No extensive areas of clayey soils are known to be present in areas covered by alluvium in the project area, including the plant site. Soil samples will be obtained for laboratory testing for expansivity during the geotechnical investigation. Other project features (linears) are considered to be less sensitive to expansive soils. Only Route 3 (fuel gas supply line) appears to cross areas that could have significant clayey soils.

Flooding. The alluvial fan, on which the power plant site is located, has been built over time, primarily by a series of flood flows originating in Pastoria Canyon. Very high velocity water flow is required to move the cobbles and boulders observed in the site vicinity. Most of these large rocks are moved as part of debris flows, which are high-density flash floods that contain as much solids as water.

Structures built upstream from the plant site as part of the California Aqueduct Project appear to reduce the exposure of the site to flooding, especially to debris flows. In particular, the siphon structure on the canal itself, and the road to the Edmonston Pumping Plant, should offer significant resistance to debris flows that otherwise would flow out onto the alluvial fan unimpeded.

Regardless of the possible protection offered by the Aqueduct structures, it appears likely that the power plant site could be affected by sustained elevated flows from the canyon when Pastoria Creek, which is incised on the order of 10 feet near the site, overflows its banks. At least two minor north-trending distributary channels cross the site. Diversion of potential flood levels will be incorporated into the design of plant grading. Refer to Section 5.5 (Water Resources) and Appendix M for more information.

Linear elements of the project cross other stream channels where flooding is likely. The effects of such floods to transmission towers and buried pipelines would be insignificant except regarding possible erosion and sedimentation as discussed below.

Erosion and Sedimentation. Alluvial soils in the project area are predominantly unconsolidated. They are particularly subject to erosion due to high velocity flood flows down the relatively steep alluvial fans in the area. At the same time flood flows from the mountains are likely to carry high sediment loads which tend to drop out of suspension and be deposited at the point where steep mountain streams flow out onto the less-steep alluvial fan.

Provisions should be made during design of the project to prevent soil erosion from flood flows on alluvial fans and from less violent but more sustained flows in existing stream channels. The burial depth of pipelines crossing stream channels will be designed to avoid pipeline exposure.

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5.3.1.2 Power Plant and Construction Laydown Area

5.3.1.2.1 Topography and Geology. The site is located on the relatively flat surface of the northward dipping alluvial fan of Pastoria Creek. Site soils are thick, very dense fanglomerate deposits composed of sand, gravel, cobbles, and boulders with very little silt and virtually no clay. Information on surficial soil characteristics is presented in Section 5.4 (Agriculture and Soils).

5.3.1.2.2 Geologic Hazards. As shown in Table 5.3-4, the plant site is subject to very strong shaking from future earthquakes. Seismic coefficients for use with the 1998 CBC are developed in Section 5.3.1.1.6. The potential for fault rupture is considered to be low, even though buried reverse faults may be present beneath the site (Goodman and Malin, 1992). There is no evidence that those faults, if they exist, offset the fanglomerate deposits.

The potential at the plant site for liquefaction, seismically induced slope failure, seismically induced settlement, regional subsidence, and collapsible or expansive soils is considered low or negligible. The potential for flooding at the site, and accompanying erosion and/or sedimentation, is considered to be moderate, requiring consideration during design of site grading.

5.3.1.3 Transmission Line Route

5.3.1.3.1 Topography and Geology. The transmission line runs south from the plant site to the head of the Pastoria Creek alluvial fan. It crosses the contact between alluvium and exposed bedrock at about MP 1.0. Goodman and Malin (1992), have mapped the buried trace of the Pleito Fault at approximately the location of that contact. The southermost portion of the alignment is over Terrace Deposits (Hoots, 1930) near mapped sandstone and shale beds that dip steeply toward the north. A landslide occurred during excavation of California Aqueduct in that area.

5.3.1.3.2 Geologic Hazards. As shown in Table 5.3-4, the route is subject to future strong seismic shaking, as are other elements of the project. The potential for future ground rupture is considered high where the route crosses the mapped trace of the Pleito Fault at MP 1.0. South of that point, the route crosses an area of possible soft, fine-grained sands and shallow groundwater, possibly ponded behind the Pleito Fault. The potential for liquefaction in that area is, therefore, considered to be low to moderate.

5.3.1.4 Water Supply Line (Route 2)

As presently planned, Route 2 is very short and adjacent to the Power Plant. Therefore, any hazard considered applicable to the plant site is also applicable to Route 2.

5.3.1.5 Fuel Gas Supply Line (Route 3)

5.3.1.5.1 Topography and Geology. Route 3, the fuel gas pipeline, consists of three alternatives, each with a different connection point to the existing Kern River/Mojave Pipeline. Generally, Route R3A extends northward from near the terminal point of Route 3, and Route 3B extends northward from the terminal point on Route R3A.

Route 3 runs eastward and then northeastward from the plant site across both younger and older alluvial fan deposits (see Figure 5.3-6). Further north (MP 2.35 – 3.5), the alignment crosses a low-lying area underlain by the relatively soft sandstones, conglomerates and shale of the Santa Maria Formation (Hoots, 1930). The remainder of the route, to its terminus at MP 11.5, is across younger and older alluvial fans. The route crosses stream channels at MP 2.2, 4.2, 5.0, 6.0 and 10.5. A bedrock fault, mapped by Hoots (1930), crosses the route at MP 1.5. The route crosses the Springs Fault, known to have moved during Quaternary time, at MP 6.7.

Route R3A extends northward, from MP 8.27 on Route 3, along low slopes underlain by sandstones and shales of the San Lorenzo Formation. From MP 11.6 to 12.2, it crosses Tejon Creek, then runs across an older alluvial fan to its terminus.

The final alternate, R3B, continues northward across older fan deposits and the more recent alluvium of Tejon Creek to Comanche Point. The Comanche Hills consist of a broad, faulted anticline that exposes the conglomerates, sandstones, and shales of the Chanac and Santa Margarita Formations. A blind thrust fault is assumed to underlie the hills (Goodman and Malin, 1992). At MP 15, the route turns to the northeast along the northern edge of the hills, parallel to the White Wolf Fault. From MP 16.5 to its terminal point at MP 18.5, it runs across recent alluvial deposits at the mouth of Comanche Creek.

5.3.1.5.2 Geologic Hazards. Geologic hazards associated with the fuel gas pipeline alternatives are summarized in Table 5.3-4. Generally, the entire route is subject to strong seismic shaking, as are all of the project elements. Future fault rupture is considered possible on several mapped faults crossed by the route, including the Pleito Fault, the Springs Fault, and especially the White Wolf Fault. The potential for liquefaction along the routes is considered greatest in Comanche valley, where ground cracking and mud volcanoes occurred during the 1952 Bakersfield Earthquake.

The potential for flooding exists at every stream crossing encountered by the routes. Of particular importance is the determination of how deep the pipeline should be buried to avoid exposure by erosion at the stream crossings. Additional studies of erosion and sedimentation potentials will be required prior to laying the pipelines.

5.3.1.6 Wastewater Discharge Line (Route 4)

5.3.1.6.1 Topography and Geology. Route 4 extends from the site, down the Pastoria Creek alluvial fan, into the Tejon Oil Field. The route is entirely through dense fanglomerate soils. The fault crosses the projection of the active Springs Fault at about MP 1.4.

5.3.1.6.2 Geologic Hazards. Route 4 runs only 1.7 miles from the plant site to the planned location of the wastewater injection well(s). Potentials for strong seismic shaking, liquefaction, settlement, subsidence, sensitive soils, and flooding are the same as for the plant site. The potential for future ground rupture due to faulting is considered to be significant where the route crosses the Springs Fault (see Figure 5.3-7).

5.3.1.7 Access Road

The access road is planned to follow a route between the site and the Edmonston Pumping Plant Road. Geologic conditions are approximately the same as for the site and Route 1 north of the Edmonston Pumping Plant road. The road appears to stop short of the mapped Pleito Fault trace at the base of the foothills and does not cross the area at the mouth of Pastoria Creek that may be prone to liquefaction.

5.3.2 Environmental Consequences

No adverse effect on geologic resources is expected from construction of the Pastoria Energy Facility components. The plant site is located in an area known to produce sand and gravel, and petroleum. No market is available for the sand present in the site vicinity. Prospecting for expansion of the existing gravel operation did not find commercial quantities of crushable gravel in the proposed site vicinity (Drummond, 1999). The Griffith Co. operation will expand operations to the southeast, away from the proposed power plant site.

No petroleum accumulations are known to be present closer to the site than the Tejon Oil Field that ends about a mile north of the power plant site. If economic deposits of petroleum are found in the future, the oil could be exploited by directional drilling from outside of the plant boundaries.

No collectable or marketable minerals are known to be present in the Pastoria Energy Facility project area.

No potential impacts have been identified in relation to the transmission and pipeline routes.

5.3.3 Mitigation Measures

The Pastoria Energy Facility will be designed in accordance with Seismic Zone 4 and CBC 1998 requirements, and will consider the results of project specific geotechnical studies. No adverse geologic effects have been identified. No mitigation measures are therefore required.

5.3.4 Significant Unavoidable Adverse Impacts

No unavoidable adverse impacts have been identified.

5.3.5 LORS Compliance

The Pastoria Energy Facility project will comply with applicable laws, ordinances, regulations, and standards (LORS) during and following construction. Applicable LORS that relate to geologic hazards and resources are included in Section 7.0.

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TABLE 5.3-1

STRATIGRAPHIC UNITS MAPPED IN PASTORIA PROJECT AREA

Hoots, 1930 (This report, Figures 5.3-5 through 9)	Bartow and Dibblee, 1981	Goodman and Malin, 1992	Composite Lithologic Description
Alluvium (Qal)	Younger Alluvium (Qya)	Alluvium (Qa, Qg)	In the Pastoria project area, younger alluvium consists of sandy to bouldery fanglomerate; fan material becomes finer-grained toward the north.
Landslide Deposits (Qls)	Landslide Material (map symbol)	Landslide Deposits (Qls)	Small area of slope failure material caused slide-prone beds (shales) and/or adversely dipping beds.
Terrace Deposits (Qt, Qtd)	Older Alluvium (Qoa1, Qoa2)	Older Alluvium (Qoa, Qog)	Sandy to bouldery fanglomerate deposits elevated above present flood plains but with dips similar to present fan deposits. Mostly Holocene in age.
Tilted Terrace Deposits (Qtd)	Kern River Formation (QTkr)	---	Older fanglomerate deposits that were tilted northward at the end of the Pleistocene epoch.
Chanac Formation (Tc)	Chanac Formation (Tch)	Chanac Formation (Tch, Tcc)	Coarse-grained Pliocene-age alluvial fan deposits.
Santa Margarita Formation (Tsm)	Santa Margarita Formation (Tsm)	Included in Chanac Formation	Upper Miocene marine sandstone, conglomerate and marly clay.
Vaqueros Formation (Tv)	Bena Gravels (Tba)	Unnamed conglomerate (Tnc)	Coarse-grained marine deposits that appear to be near-shore equivalents of clays in deeper part of basin.
Basalt (b)	not mapped	Tunis Volcanics (Tvb) member or Tecuya Formation	Volcanics are mainly Lower Miocene extrusive basalts.
San Lorenzo Formation (Tsl)	not mapped	Congl., SS, Siltstone (Ttg, Ttc) member of Tecuya Formation	Oligocene-age sedimentary rocks consist of marine sandstone and shale topped by massive conglomerate.
Tejon Formation (Ttj)	Marine Sandstone (Tss) Olcese Formation (To)	Tejon Formation (Tta, Ttm, Ttl, Ttu)	Eocene shale with fossiliferous limestone layers, limestone concretions, and minor sandstone layers.
Granodiorite and associated rocks (gd)	Hornblend-biotite Tonolite (ht); Metamorphic Rocks (m)	Tehachapi Gneiss Complex (pattern only, no symbol)	Described variably as light-colored, coarse-grained pre-Cenozoic crystalline rock (basement rock).

TABLE 5.3-2

MAJOR EARTHQUAKES WITHIN APPROXIMATELY 100 MILES OF PASTORIA ENERGY FACILITY SITE

Year	Month	North Latitude (degrees)	West Longitude (degrees)	Depth (km)	Estimated Magnitude [(1)]	Intensity [(2)]	Approximate Location
1812	December	34	118	---	7	IX	Wrightwood
1812	December	34	120	---	7	X	Purisma
1857	January	35	119	---	8.3	VII	Tejon Pass
1925	June	34.3	119.8	---	6.2	---	Santa Barbara
1952	July	35	119	---	7.7	VIII - XI	Bakersfield
1952	August	35.3	118.9	16	5.8	---	Bakersfield
1971	February	34.4	118.4	9	6.4	XI	San Fernando
1973	February	34.1	119	15	5.9	VII	Point Mugu
1978	August	34.4	119.7	7	5.6	VII	Santa Barbara
1987	October	34.1	118.2	17	6	VIII	Whittier Narrows
1987	October	34	118.2	13	5.2	VII	Whittier
1991	June	34.3	118	11	5.8	VII	Los Angeles
1994	January	34.2	118.5	18	6.8	IX	Northridge

Source: Southern California Earthquake Center web site (*www.scec.org*).

Notes: [(1)] Reported magnitude is usually ML (local Richter) or Mw (moment magnitude).

[(2)] Intensity is a subjective measure of level of shaking on a scale of 1 to 12 (Modified Mercalli Scale). For example, level V shaking is considered to be Light and includes the description: “Small unstable objects displaced or upset”. Shaking Level XI is considered to be Very Violent. An indicator of Level XI is “Underground pipelines completely out of service.”

TABLE 5.3-3

SUMMARY OF SIGNIFICANT SEISMIC SOURCES WITHIN APPROXIMATELY 100 KILOMETERS OF PASTORIA SITE

Fault Name	Displacement Style	1997 UBC Source Type	Approximate Closest Distance to Site (km) Measured Distance	Approximate Closest Distance to Site (km) 1997 UBC Distance	Estimated Slip Rate (mm/yr)	Estimated Maximum Magnitude Earthquake (Mw)
Pleito thrust	Thrust	B	1	2	1.4	7
Garlock Fault	Strike Slip	A	9.5	9.5	2 - 7	7
White Wolf Fault	Reverse	B	16	16	3 - 8.5	7
San Andreas Fault	Strike Slip	A	16	16	20 - 35	8
Big Pine Fault	Strike Slip	B	22	22	1 - 4	7
San Gabriel Fault	Strike Slip	B	27	27	1 - 5	7
Pine Mountain Fault	Reverse	C	37	37	---	---
Santa Ynez	Oblique	B	40	40	---	7
San Cayetano	Reverse	B	56	56	1.5 - 9	7
Ozena Fault	Reverse	C	58	58	---	---
Arroyo Parida	Strike Slip	C	70	70	---	7
Oakridge Fault (onshore)	Reverse	B	62	62	3.5 - 6	7
Northridge blind thrust (note 3)	Thrust	A	62	62	---	7
Santa Susana Fault	Reverse	B	64	64	5 - 7	7
Sierra Madre (San Fernando)	Reverse	B	82	82	.4 - 4	6-3/4

Notes:

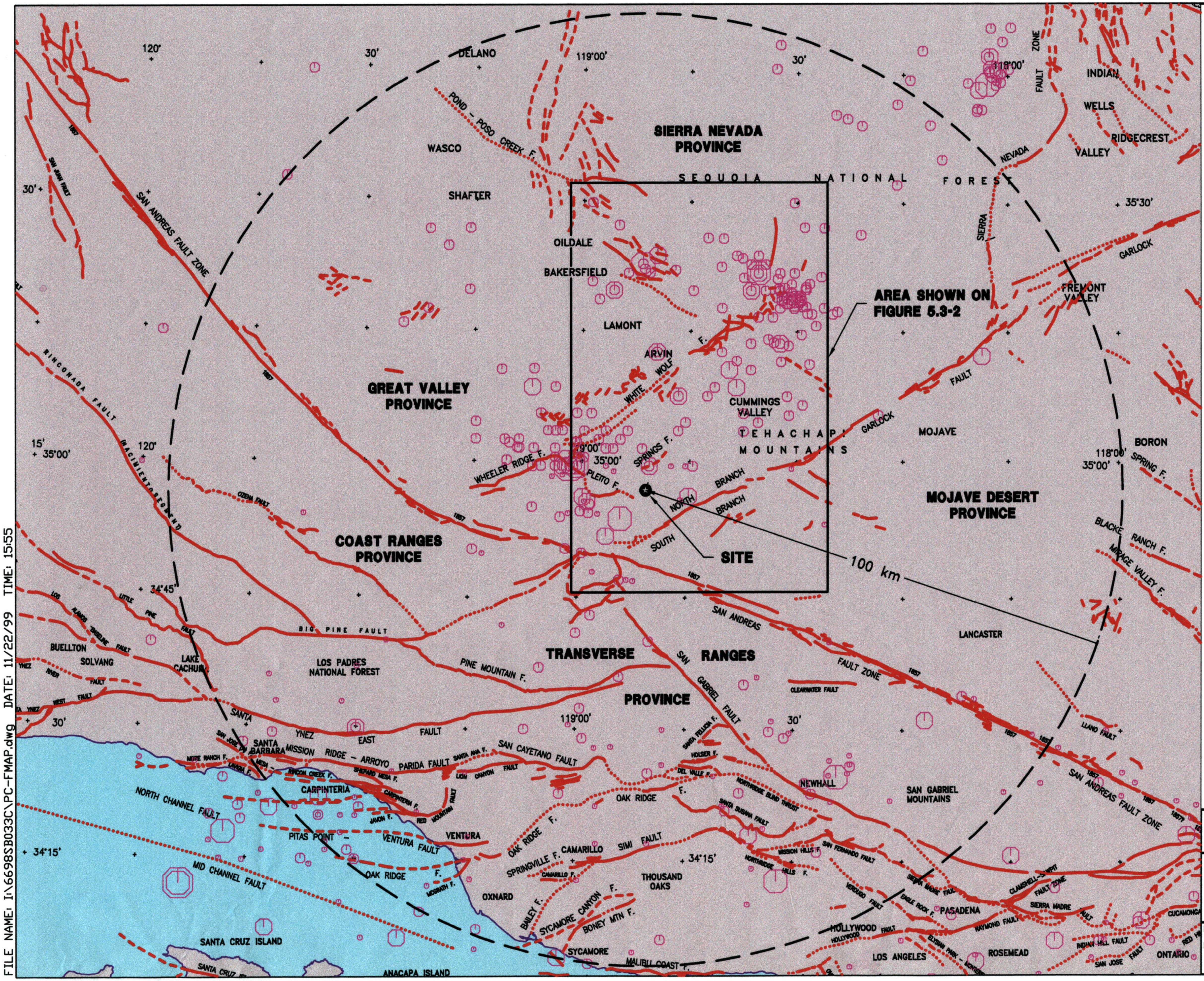
1. Source: Southern California Earthquake Center website (*www.scec.org*).
2. Dash (---) indicates that no estimate has been made.
3. Considered to be associated with the Oakridge Fault.
4. Based on the 1998 CBC, the Ca and Cv coefficients are equal to 0.40Na and 0.52Nv, respectively.

TABLE 5.3-4

SUMMARY OF POTENTIAL GEOLOGIC HAZARDS BY PROJECT COMPONENT

Project Component	Potential Geologic Hazard							
	Strong Seismic Shaking	**Fault Ground rupture**	**Liquefaction**	**Slope Failure**	**Seismically Induced Settlement**	**Regional Subsidence**	**Collapsible or Expansive Soils**	**Flooding, Erosion and Sedimentation**
Plant Site and Laydown Area	High	Low	Low	n/a	Low	Low	Low	Moderate
R1 -Transmission Line	High	High near MP1	Moderate at MP 1	Low at MP 1	Low	n/a	Low	Moderate
R2 – Water Supply Line	High	Low	Low	n/a	Low		Low	Moderate
R3 – Fuel Gas Supply Line – southern alternate	High	Moderate to High at MP1.5 & 6.7	Moderate at MP 2.2, 2-3;5-10	n/a	Low	n/a	Low	High at MP 3.3-4.7, 5.7-6.7, and 8.4-11.5
R3A –Fuel Gas Supply Line - middle alternate	High	Low	n/a	n/a	Low	n/a	Low	Moderate at MP 8.3; 11.1-11.8
R3B - Fuel Gas Supply Line - northern alternate	High	High at MP 15-16	High at MP 16-18.5	Low at MP 15-16	Low	n/a	Low	Moderate at MP 12-15; High at MP 17.5-18.5
R4 – Wastewater Discharge Line	High	High near MP 1.5	Low	n/a	Low	Low	Low	Low
R5 - Access Road	High	Low	Low	n/a	Low	n/a	Low	Moderate

Potential for element to be effected by Hazard: n/a = negligible; otherwise Low, Moderate, or High.
MP refers to area (milepost) of most concern.



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N

0 20 40

APPROXIMATE SCALE, kilometers

LEGEND

REPORTED EARTHQUAKE MAGNITUDES.

- 3.5 TO 3.9
- 4.0 TO 4.9
- 5.0 TO 5.9
- 6.0 TO 6.9
- 7.0 AND GREATER

SOUTH OF LATITUDE 35°N, EPICENTER AND MAGNITUDE DATA ARE FROM THE CALTECH EARTHQUAKE CATALOG FOR THE PERIOD FROM 1800 TO JUNE 1994. ONLY EARTHQUAKES OF MAGNITUDE 3.5 AND LARGER ARE SHOWN. AFTERSHOCKS ARE NOT INCLUDED. NORTH OF LATITUDE 35°N, DATA ARE FROM THE CNSS EARTHQUAKE CATALOG (UC BERKELEY) FOR THE PERIOD FROM 1932 TO DECEMBER, 1998. ONLY EARTHQUAKES OF MAGNITUDE 4.0 AND LARGER ARE SHOWN. SIGNIFICANT AFTERSHOCKS OF THE 1952 KERN COUNTY EARTHQUAKE ARE INCLUDED.

? ? ?

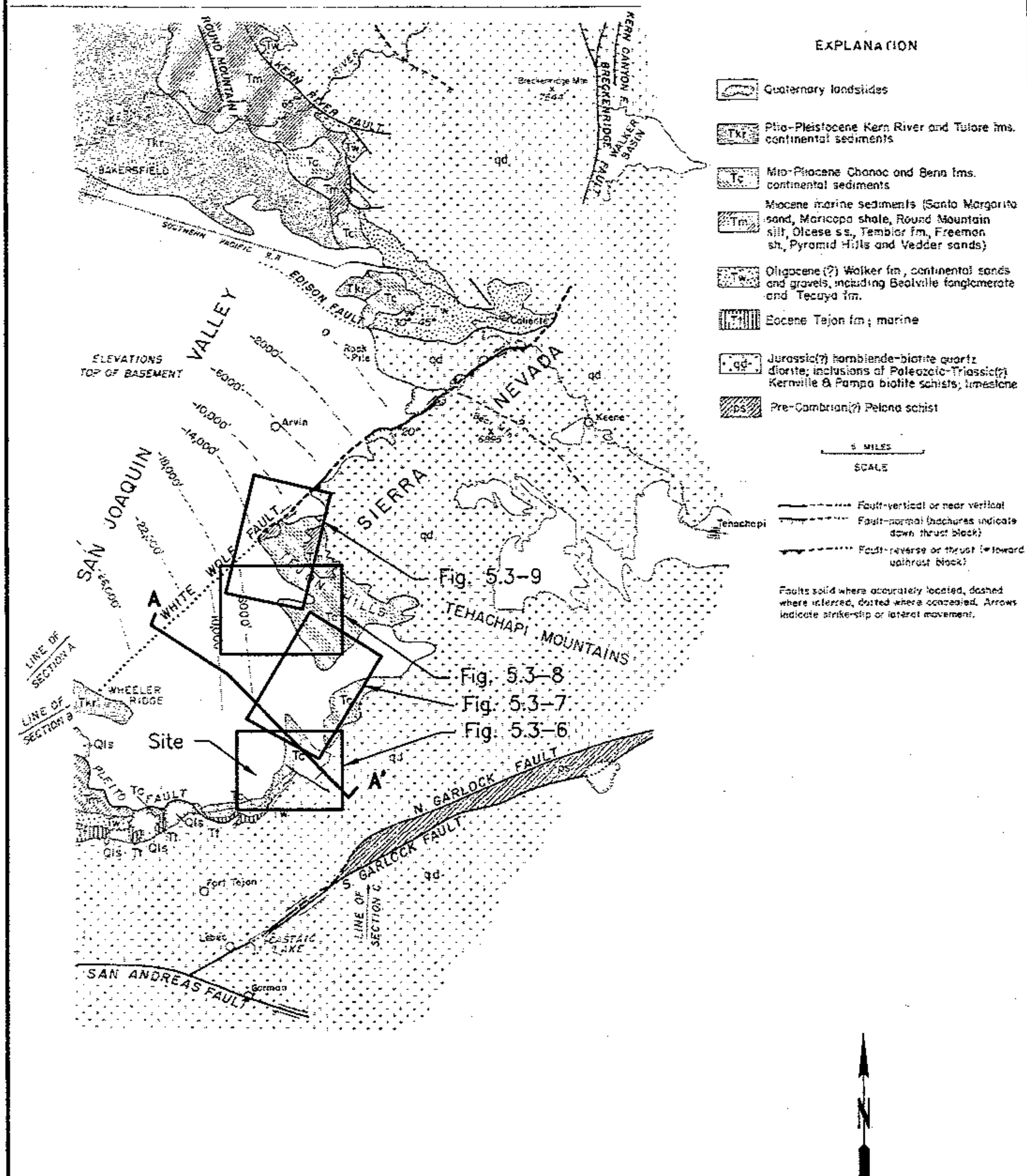
APPROXIMATE LOCATION OF HOLOCENE AND PLEISTOCENE FAULTS, DOTTED WHERE CONCEALED, QUERIED WHERE CONJECTURAL. FAULT LOCATIONS BASED ON: ZIONY AND JONES, 1989; GEOLOGIC MAP SERIES OF CALIFORNIA, 1977–1986 (1:250,000 SCALE); GEOLOGIC MAP SERIES, CALIFORNIA CONTINENTAL MARGIN, 1986–1987 (1:250,000 SCALE); HAUKSSON, 1990; AND WRIGHT, 1991.

*SITE COORDINATE
LAT. = 34°57'16" LON. = 118°50'29"

PASTORIA ENERGY FACILITY, LLC

REGIONAL FAULT AND EPICENTER MAP

Proj. No.:	6698SB033C.00	Date:	NOV. 1999
Project:	PASTORIA ENERGY FACILITY	CAD ID.:	PC-FMAP
		Figure:	5.3-1



MODIFIED FROM DIBBLEE, 1955.

REGIONAL GEOLOGIC MAP

Project No.: 6698SB033C	Date: NOV. 1999	Project: PASTORIA ENERGY FACILITY	Fig.5.3–2

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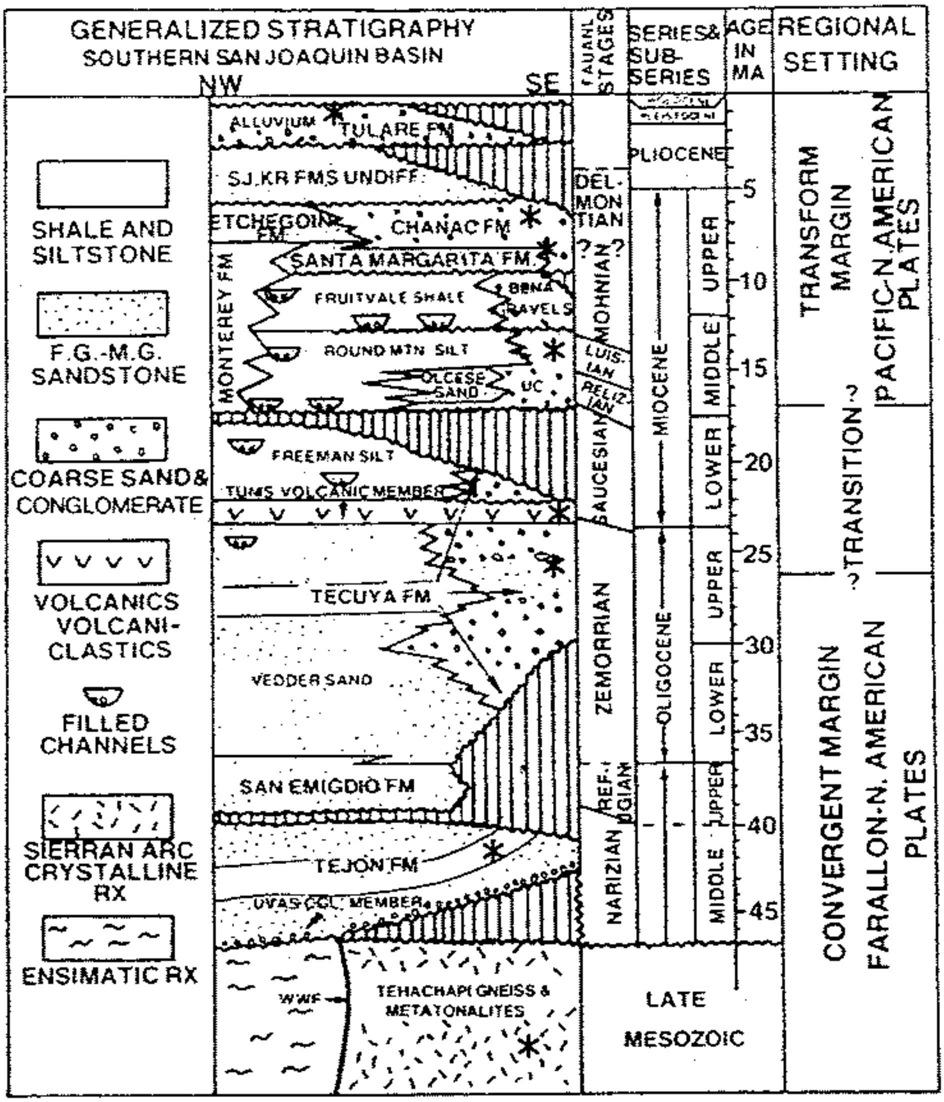
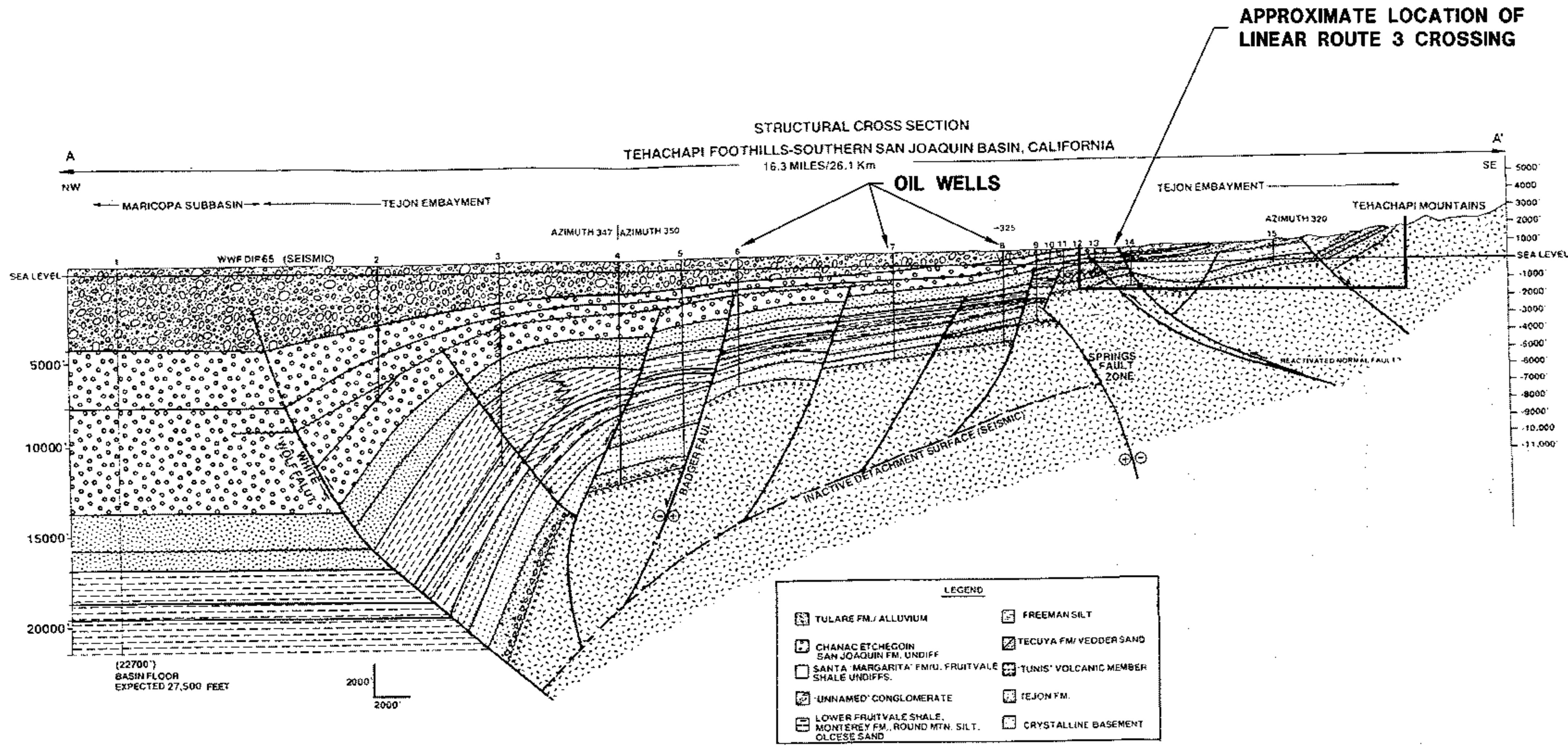


* Units present in Pastoria project areas
Modified from Goodman and Malin (1992)

Notes:
Lithostratigraphic units are depicted versus time, California foraminiferal stages [after Kleinpell, 1938, and generalized regional settings. Abbreviations are SJ, San Joaquin Formation; KR, Kern River Formation; UC, Unnamed conglomerate; WWF, White Wolf Fault; RX, rocks; CGL, conglomerate and F.G.–M.G., fine to medium grain. Vertical lines indicate eroded section.

Generalized stratigraphic column for the southern end of the San Joaquin Basin

Project No.: 6698SB033C	Date: NOV. 1999	Project: PASTORIA ENERGY FACILITY	Fig.5.3–3



MODIFIED FROM GEODMAN AND MALIN, 1992

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PASTORIA ENERGY FACILITY, LLC

CROSS SECTION A-A'

Proj. No.:	5909912007.01	Date:	NOV. 1999
Project:	PASTORIA ENERGY FACILITY	CAD ID.:	X-AA
		Figure:	5.3-4

EXPLANATION
SEDIMENTARY ROCKS

Recent

- Qal — Alluvium
- Qls — Landslides and earth flows

Pleistocene

- Qt, Qfd — Terrace deposits and tilted alluvial-fan deposits

Pliocene

- Tc — Chanac formation

Miocene

- Tsm — Santa Margarita formation
- Tv — Vaqueros formation and undifferentiated later beds

Oligocene

- San Lorenzo formation

Eocene

- Tejon and Meganos formations

IGNEOUS ROCKS

- Basalt
- Granodiorite, granite, diorite, and associated dark-colored schist

SYMBOLS

D
U
T

Faults

(Broken line, probable fault; dotted where concealed; T, thrust side of overthrust fault; D, downthrow, U, upthrow)

30°

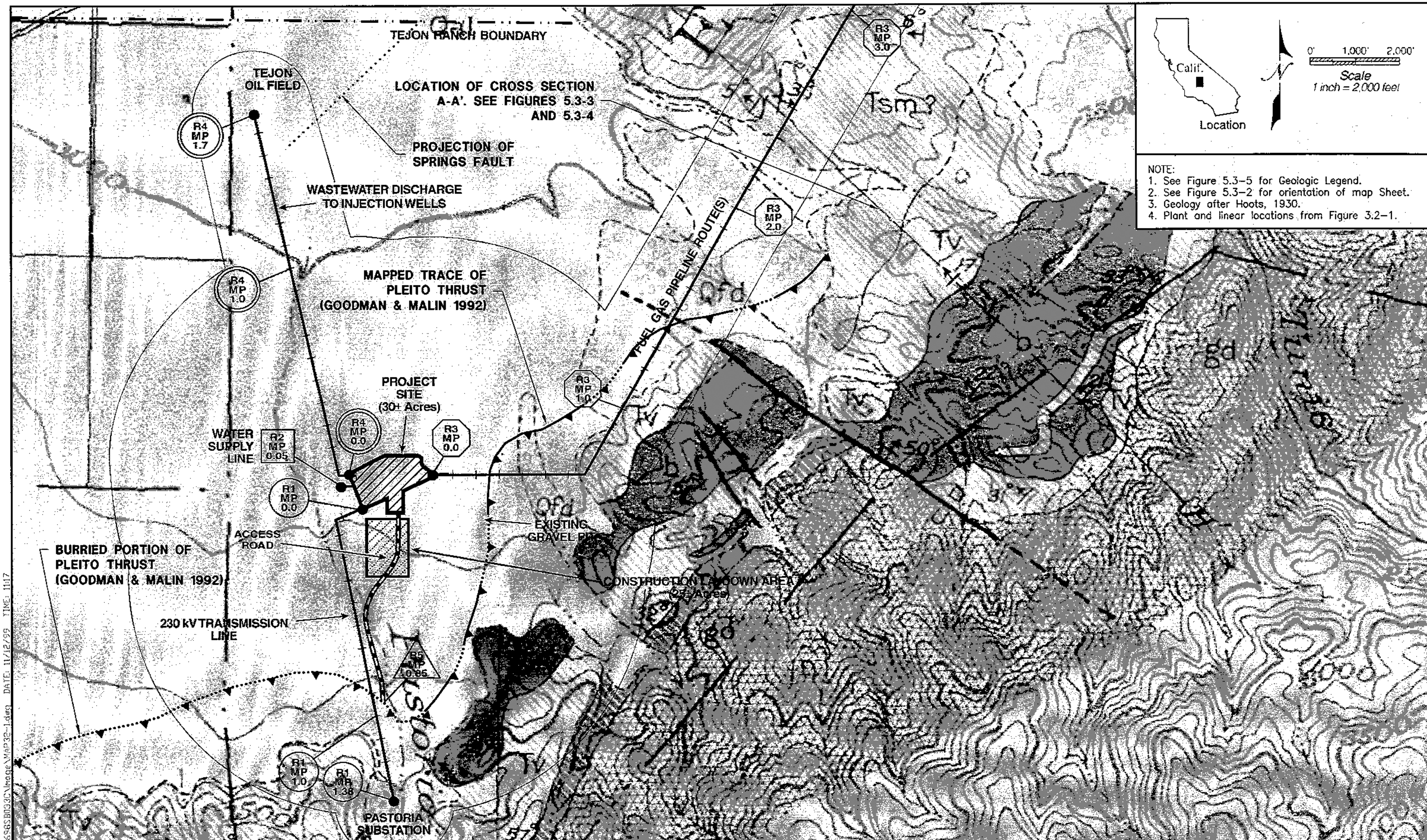
Strike and dip

Location of well

PASTORIA ENERGY FACILITY, LLC

GEOLOGIC LEGEND FOR
FIGURES 5.3-6,7,8 AND 9

Proj. No: 6698SB033C Project: PASTORIA ENERGY FACILITY	Date: Nov. 1999 File: I/JPASTORIA Figure: 5.3-5



Pastoria Energy Facility

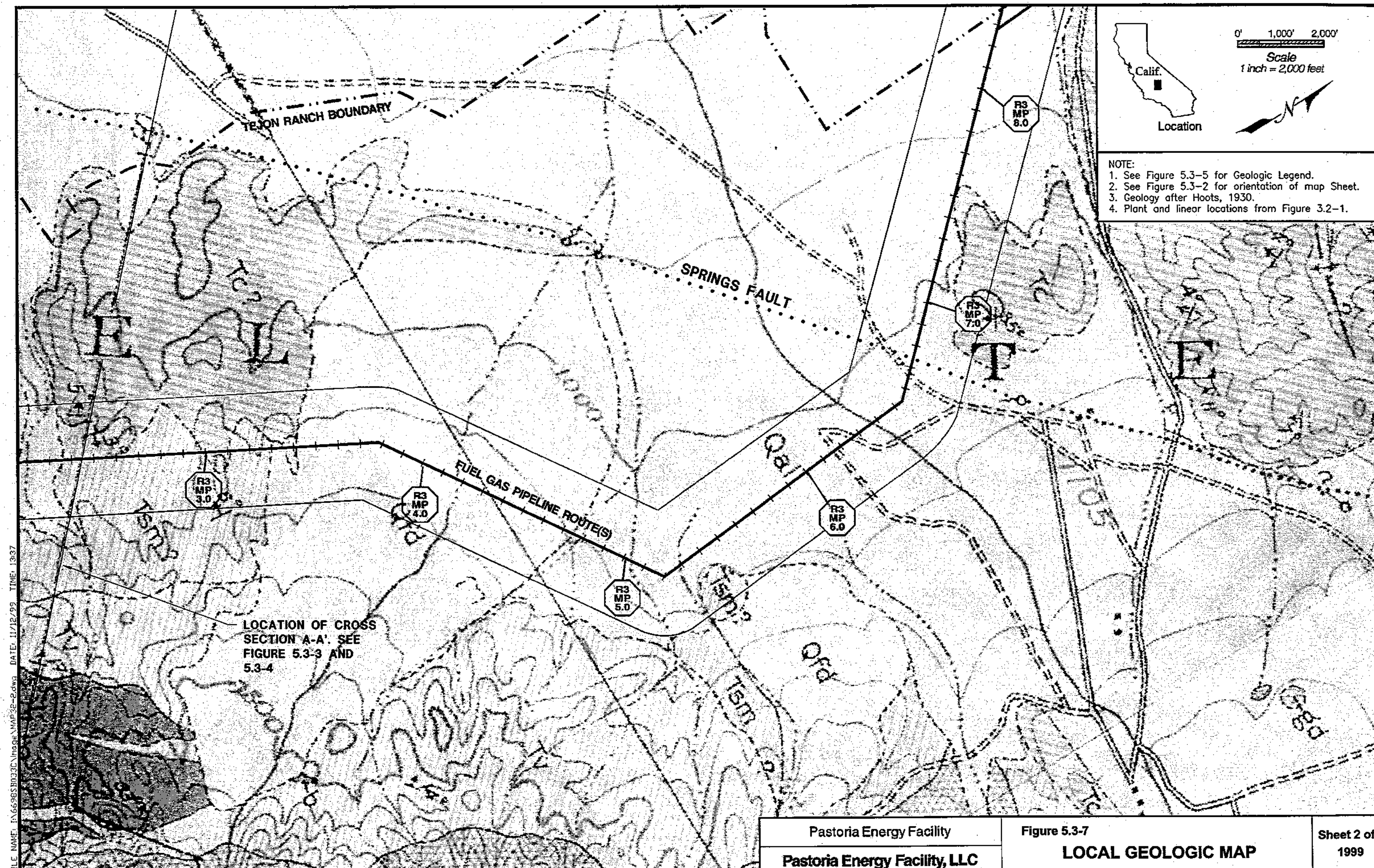
Pastoria Energy Facility, LLC

Figure 5.3-6

LOCAL GEOLOGIC MAP

Sheet 1 of 4

1999



NOTE:
1. See Figure 5.3–5 for Geologic Legend.
2. See Figure 5.3–2 for orientation of map Sheet.
3. Geology after Hoots, 1930.
4. Plant and linear locations from Figure 3.2–1.

Pastoria Energy Facility	Figure 5.3-7	Sheet 2 of 4
Pastoria Energy Facility, LLC	**LOCAL GEOLOGIC MAP**	**1999**

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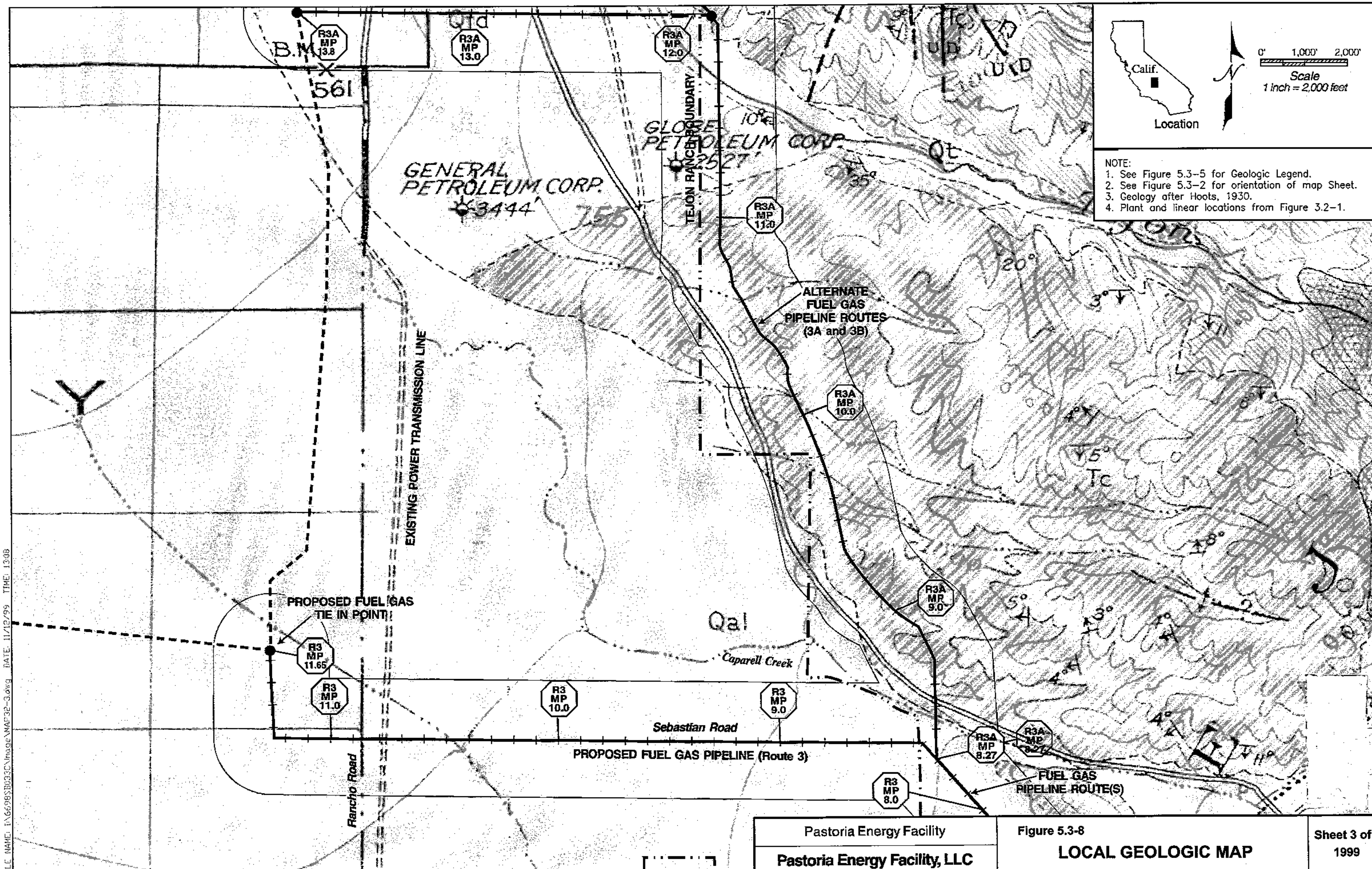

Pastoria Energy Facility

Pastoria Energy Facility, LLC

Figure 5.3-8

LOCAL GEOLOGIC MAP

Sheet 3 of 4

1999

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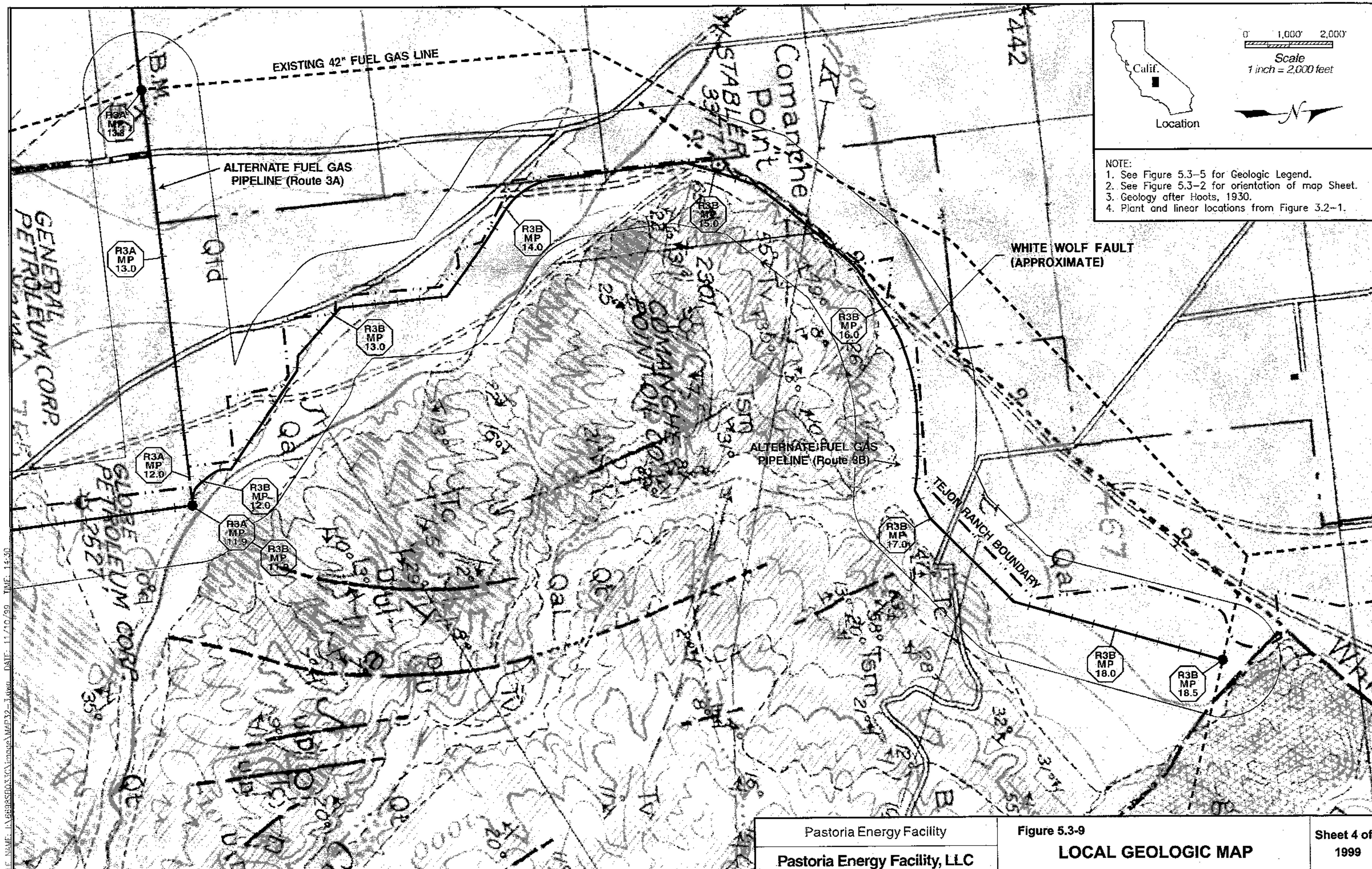

Pastoria Energy Facility

Pastoria Energy Facility, LLC

Figure 5.3-9

LOCAL GEOLOGIC MAP

Sheet 4 of 4

1999

SUMMARY OF CONSTRUCTION COMPLIANCE RELATED GEOTECHNICAL INFORMATION

ATTACHMENT B – SUMMARY OF CONSTRUCTION COMPLIANCE RELATED GEOTECHNICAL INFORMATION

1.0 PURPOSE

This Attachment provides a summary of geotechnical materials submitted as part of 99-AFC-7 as well as construction compliance proceedings regarding geotechnical materials for the existing PEF. This summary has been provided to describe the extensive documentation and compliance activities that have occurred as part of the processing of 99-AFC-7, as well as to comply with construction-related requirements. Copies of the reports summarized below are on file at the CEC as part of the compliance proceedings for the existing PEF (99-AFC-7C).

2.0 OVERVIEW

Construction compliance-related activities passed through two owners, Enron Corporation and, later, Calpine Corporation. Consequently, work for this project was conducted in multiple phases. As originally configured the PEF comprised a 30-acre power plant site, 25-acre construction laydown area, a 1.38-mile long 230 kV transmission line, a 0.5-mile long water supply line, a 11.65-mile long fuel gas pipeline, or alternate fuel gas pipelines of either 13.8 miles or 18.5 miles, a 1.7-mile long wastewater discharge line, and a 0.85-mile long access road. The final project was reconfigured to include a modified 14.01-mile gas pipeline that by-passed part of the original gas pipeline . Construction and operation of the existing PEF is conducted under a license granted by the California Energy Commission (CEC). CEC staff developed Conditions of Certification (COC) to ensure that construction of the project would not create significant direct, indirect, or cumulative adverse impacts to cultural resources. This summary describes compliance activities completed to date at the existing PEF.

3.0 BACKGROUND REPORTS

URS has been providing geotechnical services to Calpine Corporation for the PEF during both the design and construction phases of the project.

URS Corporation (URS) provided recommendations and geotechnical parameters for the design and construction of the PEF in the following reports:

URS 2000, Preliminary Geotechnical Investigation Report – Prepared for Pastoria Energy Facility, dated January 5. (Submitted as part of the initial filing in Appendix L of 99-AFC-7)

URS 2001, “Geotechnical Investigation – Proposed Pastoria Energy Facility Project- Kern County, California,” Project No. 66-00100010.01, dated May 15. (Main report that summarizes filed exploration, laboratory testing and geotechnical recommendations)

URS 2001, “Addendum 1 - Geotechnical Investigation – Proposed Pastoria Energy Facility Project- Kern County, California,” dated September 28. (Regarding foundation excavations at test pit locations)

URS 2001, “Addendum 2 - Geotechnical Investigation – Proposed Pastoria Energy Facility Project- Kern County, California,” dated November 6. (Regarding drilled pier foundations for switchyard)

URS 2001, “Addendum 3 (Additional Drilled Pier Recommendations) - Geotechnical Investigation – Proposed Pastoria Energy Facility Project- Kern County, California,” dated December 7. (Regarding drilled pier foundations for switchyard)

URS 2002, “Addendum 4 (Lateral Earth Pressures for Hydrostatic Condition) - Geotechnical Investigation – Proposed Pastoria Energy Facility Project- Kern County, California,” dated January 31. (Regarding drain materials behind walls and hydrostatic pressures)

URS 2002, “Addendum 5 – Tank Farm Foundation Excavations Geotechnical Investigation, Pastoria Energy Facility, Kern County, California,” Dated March 28. (Recommendations for Tank Farm foundation excavations)

URS 2002, “Revised Switchyard Construction Observation Report, Pastoria Energy Facility, Kern County, California,” Dated September 23.

URS 2003, “Interim Construction Observation Report, Pastoria Energy Facility,, Kern County, California,” Dated August 5.

URS 2003, “Recommendations for Subgrade Preparation, South Road, Pastoria Energy Facility, Kern County, California,” Dated October 28.

URS 2003, “Gas Facility Foundations, Pastoria Energy Facility, Kern County, California,” Dated December 15.

URS 2004, “Additional Recommendations for Subgrade Preparation, South Road, Pastoria Energy Facility, Kern County, California,” Dated April 9.

4.0 EARTHWORK OPERATIONS

The earthwork operations discussed herein were performed between August 1, 2001 and September 29, 2004. During construction activities, URS's scope of services consisted of the following:

- Providing geotechnical engineering support.
- Observing and documenting the grading activities including excavation, subgrade preparation, placement and compaction of fills and foundation subgrade.
- Preparing a report summarizing the results of our observations.

4.1 Rough Grading

Construction completed during rough grading included (URS began full time observation of site work on August 1, 2001):

- Pastoria Creek Arch Culvert.
- Access Road from Edmonston Pumping Plant Road to the Office Complex.
- Foundation Grading for the temporary Warehouse Building.
- Excavation of the Central Plant Area, Cooling Towers and Circulating Water Pipeline Corridors, Tank Farm, Switchyard, and Storm Water Detention Ponds. The excavation plan is presented on Figure 2.

4.2 Earthwork Activities following rough grading

Earthwork activities following rough grading generally consisted of the following:

- Excavation and backfilling of trenches for underground piping, electrical ducts, electrical grounding grid, and wastewater collection system
- Foundation construction
- Removal and recompaction of the geotechnical investigation test pits
- Engineered fill placement for structures and foundations
- Fine grading and Area Paving

The following sections describe the earthwork activities following rough grading.

5.0 CONSTRUCTION OBSERVATION AND TESTING

URS observed the placement and compaction of the engineered fill for the PEF on a full time basis during the construction period from August 1, 2001 to September 29, 2004.

6.0 CONCLUSIONS

Based upon URS field observations and the soils testing results presented in the Final Geotechnical Report, the earthwork operations observed between August 1, 2001 and September 29, 2004 by URS were performed in general accordance with the project specifications with modifications. Detailed geotechnical information has been compiled in the Final Geotechnical Report is expected to be submitted to the CEC within the near future.